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Results: The average annual incidence of hospitalization for a principal or secondary diagnosis of ocular trauma (total hospitalized ocular injury) was 77.1 per 100,000 persons (95% confidence interval, 75.1-79.2). There was a 38% decline in the rate of total hospitalized ocular injury during this 10-year period. Men had twice the rates of women over all age groups. The highest rate occurred in the 17- to 19-year age group, with rates of 200.7 and 123.4 per 100,000 in men and women, respectively. Whites had a higher rate than blacks and nonwhites-nonblacks. Almost a third of the injuries were contusions of the eye and adexna. Among men, the leading causes were machinery or tools (18%), and sports or training (11%). Only 7% were related to weaponry or war, and of these, 90% were from nonbattle activities.
Conclusion: The type and cause of injury suggest that preventive measures may be effective in decreasing the incidence of ocular trauma requiring hospitalization in US Army personnel.

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# Ocular Trauma in the United States Army: Hospitalization Records From 1985 Through 1994

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• PURPOSE: To determine the incidence of hospitalized ocular injury in the United States Army and evaluate specific types and external causes of these injuries.
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• CONCLUSION: The type and cause of injury suggest that preventive measures may be effective in decreasing the incidence of ocular trauma requiring hospitalization in US Army personnel. (Am J Ophthalmol 2000;129: 645–650. © 2000 by Elsevier Science Inc. All rights reserved.)

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OCULAR INJURY IS AN IMPORTANT PROBLEM IN THE armed forces. Soldiers who sustain eye injuries often become unfit for military service, and the economic cost to the military of serious eye injuries can be enormous. The proportion of ocular injuries (compared with injuries sustained by other body parts) appears to be increasing with succeeding wars in the 20th century.[1] Whereas these injuries composed only 2% to 2.5% of total body injuries in World Wars I and II,[2] this percentage was 5% to 9% in Vietnam.[3] Two recent case series of ocular injury sustained by the United States Army during the recent Gulf War highlight some of the causes and types of injuries seen during wartime.[4,5] In peacetime, however, there are few data available on the magnitude of this problem. In two reports, the proportion of ocular injuries among soldiers has been observed to be between 1.7% and 2.4% of all training injuries.[6,7]

The purpose of this study was to determine the incidence of hospitalized ocular injury in the US Army, to identify time trends, to define high-risk populations (by age, gender, and race), and to evaluate specific types and causes of these injuries. A nationwide hospital discharge database system (covering both military and civilian hospital admissions) developed by the US Army was available for this study. This database is far more comprehensive than any available for other occupational groups and gives additional information not available from civilian data, such as specific cause and circumstances surrounding the injury. In addition, the US Army maintains accurate and up-to-date denominator data for the accurate calculation of rates.

## METHODS

ALL ACTIVE US ARMY PERSONNEL DURING THE 10-YEAR period from 1985 through 1994 were included in this study

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**TABLE 1.** Ocular Trauma Discharge Diagnosis Codes From the ICD-9-CM

| Diagnosis | ICD-9-CM Code |
|---|---|
| Orbital floor fractures (including blowout fractures) | 802.6–802.7 |
| Open wounds of ocular adnexa | 870.0–870.9 |
| Open wounds of eyeball | 871.0–871.9 |
| Superficial wound of eye and adnexa | 918.0–918.9 |
| Contusion of eye and adnexa | 921.0–921.9 |
| Foreign body on external eye | 930.0–930.9 |
| Burn confined to eye and adnexa | 950.0–950.9 |
| Burn involving eye with other parts of face, head, and neck | 941.02–941.52 |
| Injury to optic nerve and pathways | 950.0–950.9 |
| Injury to oculomotor, trochlear, and abducens nerve | 951.0, 951.1, 951.3 |

ICD-9-CM = International Classification of Diseases, Ninth Revision, Clinical Modification.

and composed the denominators for calculation of incidence rates. Data were obtained from the Total Army and Health Outcomes Database, a collection of administrative databases within the Army.[8] Demographic data are updated semiannually, and data by person-months for each soldier can be calculated and translated to total person-years of exposure. The existence of a unique identifier (a scrambled social security number) enabled us to analyze the true incidence rate of ocular injury and eliminate repeated admissions for the same injury.[9]

Ocular injuries requiring hospitalization were recorded in an Army-wide hospital discharge database, which covered all hospitalizations in military and civilian hospitals. This database included patient demographics, type of injury (International Classification of Diseases, Ninth Revision–Clinical Modification [ICD-9-CM] codes, in eight diagnostic fields), cause and nature of injury, and length of hospitalization stay. Information on cause of injury was coded by means of military STANAG codes, which are based on ICD-9 – E codes but adapted for military use.[8]

For this study, ocular injuries were defined as any injury or foreign body affecting the eye or adnexa (excluding the eyebrow). These were coded using the ICD-9-CM codes as shown in Table 1. We used the same definitions of principal and secondary diagnosis as previously reported.[10–12] The *principal diagnosis* is defined as the condition that, after investigation, was determined to be the main reason for admission to hospital, listed in the first diagnostic field of the hospital discharge form. The *secondary diagnosis* refers to those hospital admissions for which ocular trauma was not the principal diagnosis but which listed an ocular trauma code as an additional diagnosis in any of the seven secondary diagnosis fields (for example, eye injuries as part of multiple injuries resulting from a car crash). *Total hospitalized ocular injury* refers to either a principal or a secondary diagnosis of ocular trauma (that is, ocular trauma code in any of the eight diagnostic fields). Incidence rates with the use of all the three case definitions were calculated. However, results presented here are based on the *total hospitalized ocular injury* unless otherwise stated. Significant differences between this and either the principal or the secondary diagnosis group are highlighted.

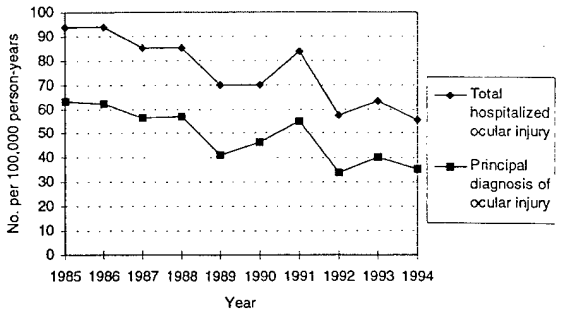


**FIGURE 1.** Rate of ocular injuries requiring hospitalization, US Army, 1985–1994.

Incidence rates of ocular injury were calculated by summing the person-year denominator for each year and dividing the number of ocular injury episodes during this period by the total person-years of exposure during that period. Age-adjusted relative risks and 95% confidence intervals were used in the comparison of ocular injury rates between demographic strata (for example, men vs women). Simple linear regression was used to allow an estimation of the effect of time on incidence rates.

This study was approved by the institutional review board of the Johns Hopkins School of Public Health, Baltimore, Maryland.

## RESULTS

FROM 1985 THROUGH 1994, 5,450 US ARMY PERSONNEL WERE hospitalized with a principal or secondary discharge diagnosis of ocular injury (total hospitalized ocular injury), an average annual incidence of 77.1 per 100,000 (95% confidence interval 75.1–79.2). Of these hospitalizations, ocular injury was the principal diagnosis in 3,538 cases (64.9%), an average annual incidence of 50.0 per 100,000 (95% confidence interval, 48.5–51.8). There was a decline in the rate of injury over time (Figure 1) and in the frequency of injury from 726 in 1985 to 303 in 1994. A linear regression fit to these data showed a 38.4% decline in total hospitalized ocular injury (that is, 4.2 injuries per 100,000 annually) and a 62% decline in the rate for a principal diagnosis of ocular injury, (that is, 3.1 injuries per 100,000 annually). We further analyzed the data to see if

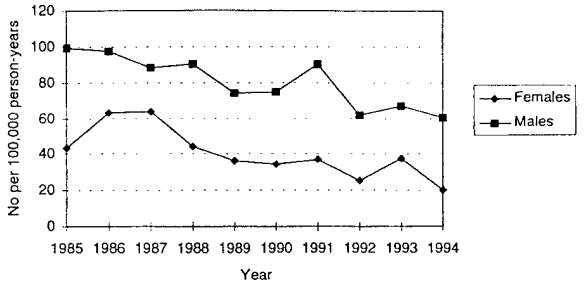


FIGURE 2. Rate of total hospitalized ocular injury, by gender, US Army, 1985–1994.

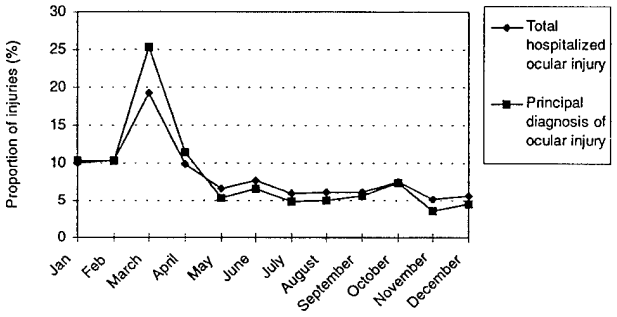


FIGURE 3. Distribution of ocular injuries in 1991.

differences existed in rates between men and women (Figure 2). There was a 36.5% decline in rate of ocular injury for men compared to a 54.3% decline in women. The length of hospital stay also declined over time (data not shown). Overall, 12.3% of ocular injuries required less than 1 day of hospitalization, 20.5% 1 day, 15.4% 2 days, 17.4% 3 to 4 days, 19.2% 5 to 9 days, and the remainder 10 or more days.

The higher rate of injury seen in 1991 can be attributed to men in the Persian Gulf War. When the 603 injuries in 1991 were analyzed by month (Figure 3), it was evident that the highest proportion of injuries occurred in March 1991 and predominantly in men (20% of all ocular injuries in 1991 for men compared with 10% for women). This corresponded to the peak of military activity during the ground phase of the war (Desert Storm phase of the Persian Gulf War).

Eye injury rates varied by age and gender (Figure 4), with the highest rates among the youngest personnel, 17 to 19 years of age. The average annual incidence was 220.7 and 123.4 per 100,000 in men and women, respectively, with a progressive decline in hospitalization rates with increasing age. Men had a higher rate of injury than women over the entire age range. The crude average annual gender-specific incidence was 81.7 (95% confidence interval, 79.5–84.0) and 40.9 (95% confidence interval, 36.5–45.4) per 100,000 in men and women, respectively. The age-adjusted relative risk for men compared with women was 2.0 (95% confidence interval, 1.95–2.13).

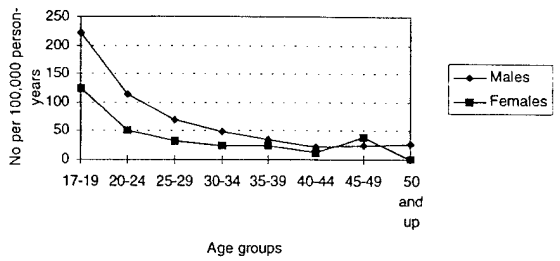


FIGURE 4. Rate of total hospitalized ocular injury, by age and gender, US Army, 1985–1994.

Whites had the highest overall incidence of injury. The average annual incidence of white men and women (87.1 and 47.3 per 100,000, respectively) exceeded that of black men and women (72.9 and 35.7). The lowest rates occurred among personnel who were neither white nor black (63.7 and 25.4). Small numbers in this group prevented meaningful breakdown into specific ethnicity.

The types of total hospitalized ocular injury varied by gender (Table 2). The five leading types in men were contusion of the eye and adnexa (31.6%), open wound of ocular adnexa (15.5%), superficial wound of eye and adnexa (14.8%), open wound of eyeball (14.3%), and orbital fracture (13.2%). Superficial wound of eye and adnexa accounted for almost a third of the injuries (29.6%) among women. In fact, the rate of hospitalization for this category of injury was identical between men and women (12.1 per 100,000/year). Analysis was repeated separately for principal and secondary diagnosis of hospitalized ocular trauma. Except for open wound of the eyeball (higher rates in the principal diagnosis group) and open wound of ocular adnexa (higher rates in the secondary diagnosis group), the data were essentially similar to those for total hospitalized ocular injury. The rate of admission for orbital fracture showed a 30% increase during the 10 years that was marginally significant ($P = .055$). No significant time trend was observed in the rates for open wound of the eyeball. On the other hand, rates for foreign body injury, contusion of the eyeball and adnexa, superficial wounds to the eye, open wound of eye and adnexa, and burns to the eye all showed statistically significant declines, ranging from 45% to 55%.

The most common external causes were incidents related to machinery and tool usage, motor vehicles, and sports (Table 3). Eighty-five percent of motor vehicular crashes occurred in nonmilitary vehicles. The single most common cause of ocular injury requiring hospitalization was assault (1,001 cases, 18.4% of total injuries). For sports-related injuries, basketball (116 cases, 19.5% of sports-related injuries) and baseball (110 cases, 18.0% of sports-related injuries) were the most frequent causes. Only 401 cases (7.4%) were war or weapon–related inju-

**TABLE 2.** Types of Total Hospitalized Ocular Injury, by Gender, US Army, 1985–94

| | Males | | | Females | | | All | | |
|---|---|---|---|---|---|---|---|---|---|
| | No. | % | Rate per 100,000/y | No. | % | Rate per 100,000/y | No. | % | Rate per 100,000/y |
| Contusion of eye and adnexa | 1,620 | 31.6 | 25.8 | 87 | 26.9 | 11.0 | 1,707 | 31.3 | 24.1 |
| Open wound of ocular adnexa | 794 | 15.5 | 12.6 | 38 | 11.7 | 4.8 | 832 | 15.3 | 11.8 |
| Superficial wound of eye and adnexa | 759 | 14.8 | 12.1 | 96 | 29.6 | 12.1 | 855 | 15.7 | 12.1 |
| Open wound of eyeball | 733 | 14.3 | 11.7 | 28 | 8.6 | 3.5 | 761 | 14.0 | 10.8 |
| Orbital floor fracture | 674 | 13.1 | 10.7 | 31 | 9.6 | 3.9 | 705 | 12.9 | 10.0 |
| Burn confined to eye and adnexa | 199 | 3.9 | 3.2 | 20 | 6.2 | 2.5 | 219 | 4.0 | 3.1 |
| Foreign body on external eye | 159 | 3.1 | 2.5 | 15 | 4.6 | 1.9 | 174 | 3.2 | 2.5 |
| Injury to optic nerve and pathway | 92 | 1.8 | 1.5 | 2 | 0.6 | 0.3 | 94 | 1.7 | 1.3 |
| Burn involving eye with other parts of face, head, and neck | 59 | 1.2 | 0.9 | 5 | 1.5 | 0.6 | 64 | 1.2 | 0.9 |
| Injury to oculomotor, trochlear, and abducens nerves | 37 | 0.7 | 0.6 | 2 | 0.6 | 0.3 | 39 | 0.7 | 0.6 |
| Total | 5,126 | 100.0 | 81.7 | 324 | 100.0 | 40.9 | 5,450 | 100.0 | 77.1 |

ries during the study period. Of these, non–battle-related injuries accounted for 361 (90% of war or weapon injuries).

## DISCUSSION

APPROXIMATELY 2.5 MILLION OCULAR INJURIES ARE ESTIMATED to occur each year in the United States.[13] A quarter to half of these injuries are work-related.[14–16] A recent statewide population-based study in California using hospital discharge data estimated an annual incidence of severe ocular injury in the workplace of 1.76 or 2.98 per 100,000 employed persons when ocular trauma was defined as either the "principal discharge diagnosis" or the "principal or secondary discharge diagnosis," respectively.[17] However, there was no information on the external causes of injuries in this study, information that is important for the design of cost-effective prevention strategies.

The US Army is a special occupational group with potential for a high risk of injury to many parts of the body in both wartime and peacetime. Our rates of eye injury in the military are much higher (77.1 per 100,000 overall) than the rates observed in the study by Baker and associates,[17] even when allowing for the fact that not all of our injuries were occupationally related. As with studies of civilian outpatient data, machinery and tools are the leading cause of eye injuries in our study (Table 3). The finding of assault being the second leading source of eye injury highlights the role of off-duty activities and high-risk behavior in this population and is consistent with reports based on civilian populations.[10] Efforts to resolve conflicts by nonviolent means and changes in drinking behavior may be effective in reducing this burden of assault-related injuries.

In wartime, eye injuries compose an exceptionally high proportion of injury in soldiers when compared with other parts of the body, given that the ocular surface area is less than 1% of the body surface and less than 5% of the face. For example, in the Vietnam War, between 5% and 9% of all injuries were eye related.[3] In the Gulf War, Heier and associates[4] observed that 13% of all injuries were ocular, although this report included patients who suffered mild injuries. The effect of the Gulf War was shown in our peak of injuries in March 1991 (Figures 2 and 3), which was the time of peak deployment. It should be noted, however, that in peacetime only 7.6% of our injuries were related to weapons and few occurred in conflict situations, where controls on wearing eye protection are more difficult to implement.

Our finding that the highest rates of injuries were in the 17- to 19-year age group and in men is not surprising and has been identified from previous civilian reports.[10–12,16] Differences in injury rates by age and gender may be associated with variations in occupational exposures. For example, men are more likely than women to be assigned to combat units as high-risk infantrymen. Unfortunately, we did not have reliable data on occupation for this study. Surprisingly, we found the rates of ocular injury to be highest in whites and lowest in personnel neither white nor black, whereas in Baker and associates' study, Hispanics had a higher risk of injury than any other racial group.[17] This again may be related to occupational exposure, but data are not available.

Downward time trends for hospitalized ocular injury were noted in the civilian sector by Tielsch and associates,[10] who attributed the decline in hospitalization rates to changes in the payment system and the treatment of certain injuries outside of hospitals. Changing indications for hospitalization may also account for our observed data.

**TABLE 3.** External Causes of Total Hospitalized Ocular Injury, by Gender, US Army, 1985–94

| | Males | | | Females | | | All | | |
|---|---|---|---|---|---|---|---|---|---|
| | No. | % | Rate per 100,000/y | No. | % | Rate per 100,000/y | No. | % | Rate per 100,000/y |
| Machines/tools | 1,062 | 20.7 | 20.7 | 66 | 20.4 | 8.3 | 1,128 | 20.7 | 16.0 |
| Piercing/cutting tools | 162 | 3.2 | 3.2 | 2 | 0.6 | 0.3 | 164 | 3.0 | 2.3 |
| Foreign body entering eye | 515 | 10.0 | 10.0 | 39 | 12.0 | 4.9 | 554 | 10.2 | 7.8 |
| Falling/projected object | 176 | 3.4 | 3.4 | 3 | 0.9 | 0.4 | 179 | 3.3 | 2.5 |
| Static objects | 95 | 1.9 | 1.9 | 5 | 1.5 | 0.6 | 100 | 1.8 | 1.4 |
| Machines | 18 | 0.4 | 0.4 | 0 | 0.0 | 0.0 | 18 | 0.3 | 0.3 |
| Tools | 46 | 0.9 | 0.9 | 0 | 0.0 | 0.0 | 46 | 0.8 | 0.7 |
| Others | 50 | 1.0 | 1.0 | 17 | 5.2 | 2.1 | 67 | 1.2 | 0.9 |
| Assault | 965 | 18.8 | 18.8 | 36 | 11.1 | 4.5 | 1,001 | 18.4 | 14.2 |
| Transport accidents | 908 | 17.7 | 17.7 | 64 | 19.8 | 8.1 | 972 | 17.8 | 13.7 |
| Nonmilitary vehicle accidents | 775 | 15.1 | 15.1 | 57 | 17.6 | 7.2 | 832 | 15.3 | 11.8 |
| Military vehicle accidents | 92 | 1.8 | 1.8 | 5 | 1.5 | 0.6 | 97 | 1.8 | 1.4 |
| Nontraffic accidents | 32 | 0.6 | 0.6 | 2 | 0.6 | 0.3 | 34 | 0.6 | 0.5 |
| Others | 9 | 0.2 | 0.2 | 0 | 0.0 | 0.0 | 9 | 0.2 | 0.1 |
| Sports | 594 | 11.6 | 11.6 | 15 | 4.6 | 1.9 | 609 | 11.2 | 8.6 |
| Basketball | 116 | 2.3 | 2.3 | 0 | 0.0 | 0.0 | 116 | 2.1 | 1.6 |
| Baseball/softball | 107 | 2.1 | 2.1 | 3 | 0.9 | 0.4 | 110 | 2.0 | 1.6 |
| Squash/handball | 73 | 1.4 | 1.4 | 3 | 0.9 | 0.4 | 76 | 1.4 | 1.1 |
| Football | 83 | 1.6 | 1.6 | 1 | 0.3 | 0.1 | 84 | 1.5 | 1.2 |
| Soccer | 29 | 0.6 | 0.6 | 1 | 0.3 | 0.1 | 30 | 0.6 | 0.4 |
| Boxing | 15 | 0.3 | 0.3 | 0 | 0.0 | 0.0 | 15 | 0.3 | 0.2 |
| Hockey | 3 | 0.1 | 0.1 | 0 | 0.0 | 0.0 | 3 | 0.1 | 0.0 |
| Others | 168 | 3.3 | 3.3 | 7 | 2.2 | 0.9 | 175 | 3.2 | 2.5 |
| War/weapon | 389 | 7.6 | 7.6 | 12 | 3.7 | 1.5 | 401 | 7.4 | 5.7 |
| Battle injuries (enemy fire) | 35 | 0.7 | 0.7 | 1 | 0.3 | 0.1 | 36 | 0.7 | 0.5 |
| Battle injuries (friendly fire) | 4 | 0.1 | 0.1 | 0 | 0.0 | 0.0 | 4 | 0.1 | 0.1 |
| Nonbattle injuries | 350 | 6.8 | 6.8 | 11 | 3.4 | 1.4 | 361 | 6.6 | 5.1 |
| Falls | 238 | 4.6 | 4.6 | 24 | 7.4 | 3.0 | 262 | 4.8 | 3.7 |
| Fire | 207 | 4.0 | 4.0 | 16 | 4.9 | 2.0 | 223 | 4.1 | 3.2 |
| Poisons | 37 | 0.7 | 0.7 | 3 | 0.9 | 0.4 | 40 | 0.7 | 0.6 |
| Environmental | 20 | 0.4 | 0.4 | 6 | 1.9 | 0.8 | 26 | 0.5 | 0.4 |
| Miscellaneous | 706 | 13.8 | 13.8 | 81 | 25.0 | 10.2 | 787 | 14.4 | 11.1 |
| Parachute accidents | 13 | 0.3 | 0.3 | 0 | 0.0 | 0.0 | 13 | 0.2 | 0.2 |
| Others | 689 | 13.4 | 13.4 | 81 | 25.0 | 10.2 | 770 | 14.1 | 10.9 |
| Unknown | 4 | 0.1 | 0.1 | 0 | 0.0 | 0.0 | 4 | 0.1 | 0.1 |
| Total | 5,126 | 100.0 | 81.6 | 324 | 100.0 | 40.9 | 5,450 | 100.0 | 77.1 |

This is supported by the fact that rates of admissions for more severe injuries (such as orbital floor fractures and open globe injuries) were constant, while minor injuries (such as foreign body injury and superficial wounds to the eye) showed significant declines in hospitalizations during the study period.

Other high-risk occupational groups have been described for ocular injury. In a study of the chemical industry, an incidence of 2,300 eye injuries per 100,000 worker-years was observed.[18] In the automotive industry, a study estimated an incidence rate of 1,500 eye injuries per 100,000 worker-years in 33 United Auto Workers–Chrysler facilities.[19] Both reports, however, included minor eye injuries not requiring hospitalization and therefore cannot be directly compared to this study.

Despite the magnitude of the problem in a high-risk group such as the military, primary prevention by the use of protective eyewear (eye armor) is possible and has been shown to be efficacious.[20–22] However, military eye protection programs themselves are less effective; few soldiers given protective armor use it, even during wartime.[5] There are a number of reasons soldiers do not use eye armor. These include organizational attitude toward eye protection programs in the military, the soldier's perception of low risk of eye injury, as well as poor design and comfort of available eye armor.[23] An understanding of these factors is

useful in the development of effective strategies toward prevention of eye injury in the military.

Although the strengths of this database include the completeness of data, unique identifier to identify repeat admissions, precise denominators, and detailed information on external causative factors of injury, there are several limitations. The quality of the hospital discharge data in different hospitals and different states may vary and may not always reflect a final clinical diagnosis. There was limited information on exposure, visual outcomes, complications, and ocular disability. Nor was use of eye protection by the individual soldier during wartime and training recorded. Finally, the rates are likely to greatly underestimate the true incidence of all eye injuries in the military because hospitalized cases do not capture less severe conditions.

In conclusion, this report highlights the magnitude of severe ocular injury requiring hospitalization in the US Army and can be the basis for future preventive strategies. In particular, it should be noted that most injuries were contusions, superficial wounds, or adnexal injuries (Table 2). Furthermore, few of the injuries occurred in combat activities (Table 3), and the leading causes in peacetime are similar to civilian activities (injuries occurring from machines, tools, transport, and sports). We therefore believe that appropriate preventive measures (such as use of protective eyewear) may be effective in decreasing the incidence of ocular trauma requiring hospitalization in the military.

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